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Marine Research
1959 No. 4

Halibut—Observations on its Size at First Maturity, Sex Ratio and Length/Weight Relationship

By BENNET B. RAE, M.A., B.Sc., Ph.D.

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Halibut—Observations on its Size at First Maturity, Sex Ratio and Length/Weight Relationship

INTRODUCTION AND SOURCE OF MATERIAL

While investigating a parasitic infestation of halibut, *Hippoglossus hippoglossus* (L.), landed at Aberdeen over the years 1952 to 1956 (Rae 1958), information was also collected of general biological interest relating to this species. This included observations on the sex and condition of the reproductive organs and numerous notes on the length and weight of halibut of more than 24 inches in length. An examination of these data has added appreciably to knowledge of this valuable fish particularly in regard to its size at first maturity and to its length/weight relationship.

Observations on the fish market were made under conditions which seldom permitted detailed work. Macroscopic examination of the reproductive organs and the determination of the extent of their development towards maturity, for example, had to be carried out quickly and often under unfavourable conditions. Some difficulty was experienced in ascertaining the stage of maturity of certain male fish but in general the maturity assessments, based on wide experience of halibut and other species on the Scottish research vessels, were made with confidence in the methods adopted.

The international scientific scale of seven maturity stages, from immature to spent, was employed throughout the investigation of the condition of the reproductive organs. For convenience, however, both in the handling of the records and in their presentation, the stages have been grouped in three categories.

1. Immature Fish—Stages I and II, representing immature fish and those exhibiting the initial changes in the ripening process.
2. Maturing Fish—Stages III, IV, V and VI, including all fish maturing for the first time, with gonads ranging from a quarter ripe to ripe.
3. Spent Fish—Stage VII, comprising spent fish and those showing varying degrees of recovery.

Halibut from all fishing grounds visited by Aberdeen vessels were included in the survey. Although data from the various grounds were recorded separately, regional differences were not always sufficiently marked to justify the separation of results on a regional basis. Length measurements were made to the nearest inch and weight measurements to the nearest quarter of a stone ($3\frac{1}{2}$ pounds) below the actual weight. The latter were the official weights recorded by the market staff prior to the sale of the fish and in every case represent "gutted" weights.

LENGTH OF HALIBUT AT FIRST MATURITY

The records of these investigations are presented in Table I. Fish of less than 24 inches have not been included since it has been established by the examination of hundreds of fish on research vessels that halibut of this size are immature with occasional individuals approaching the first stages of maturation. Although collected on a monthly basis the records have been assembled in half-yearly periods. Maturing fish were identified in nearly every month. Some of these in the first six months of the year would undoubtedly have spawned in that spawning season but it is equally certain that others would not have done so. This latter conclusion is based on the capture of quarter to three-quarter ripe fish (Stages III to V) throughout the second half of the year—a feature which suggests that some fish have a prolonged adolescent life. The scarcity of ripe or spawning fish in commercial catches is not unexpected since the halibut is known to spawn in very deep water beyond the depth range of fishing vessels (Tåning, 1936).

TABLE I

Maturity in Relation to Length in Halibut—All Regions

MALE							FEMALE					
January to June			July to December				January to June			July to December		
Immature	Maturing	Spent	Immature	Maturing	Spent	Length Inches	Immature	Maturing	Spent	Immature	Maturing	Spent
7	—	—	—	—	—	24	11	—	—	4	—	—
4	—	—	—	—	—	25	6	—	—	4	—	—
15	—	—	2	—	—	26	10	—	—	1	—	—
7	—	—	2	—	—	27	8	—	—	3	—	—
4	2	—	2	—	1	28	3	—	—	3	—	—
7	3	—	5	2	—	29	12	—	—	1	—	—
18	3	4	7	2	1	30	26	—	—	7	—	—
11	2	1	6	1	1	31	16	—	—	13	—	—
8	4	1	11	4	2	32	16	—	—	15	—	—
9	4	3	7	3	1	33	15	—	—	14	—	—
6	4	3	3	1	3	34	23	—	—	7	—	—
1	8	6	4	1	5	35	10	—	—	19	—	—
4	5	15	6	3	5	36	27	—	—	14	—	—
1	4	5	1	6	3	37	18	—	—	8	—	—
—	1	5	1	4	—	38	7	1	—	14	—	—
2	2	14	—	2	2	39	12	1	3	8	—	—
1	1	4	—	—	3	40	11	3	1	8	1	—
—	1	12	—	2	4	41	11	2	—	11	1	—
—	2	14	—	3	3	42	13	5	8	8	1	1
—	—	8	—	—	3	43	7	3	6	4	1	—
—	—	2	—	1	1	44	3	2	—	3	—	2
—	1	4	—	—	1	45	5	3	6	1	—	—
—	1	2	—	—	4	46	4	—	4	2	—	2
—	—	4	—	—	2	47	2	—	7	1	2	1
—	—	10	—	—	3	48	2	3	14	7	3	2
—	1	6	—	—	4	49	—	1	7	—	—	2
—	—	2	—	—	2	50	1	2	3	—	—	4
—	—	3	—	1	3	51	—	2	7	—	—	1
—	—	3	—	1	2	52	—	—	5	1	3	2
—	—	2	—	—	1	53	—	1	7	—	—	4
—	—	6	—	—	3	54	2	1	23	—	2	7
—	—	—	—	—	1	55	—	—	8	—	—	1
—	—	—	—	—	1	56	—	—	2	—	—	4
—	—	1	—	—	—	57	—	—	10	—	—	4
—	—	—	—	—	—	58	—	—	4	—	—	3
—	—	—	—	—	—	59	—	—	8	—	—	5
—	—	1	—	—	—	60	—	—	13	—	—	9
—	—	—	—	—	—	61-85	—	—	52	—	—	43

Table I shows that male halibut were found in the immature condition up to a length of 40 inches (102 cm) and females up to 54 inches (137 cm). The smallest spent male was 28 inches (71 cm) in length and the smallest spent female 39 inches (99 cm). A few maturing males, ranging in size from 41 to 52 inches, show that male fish may occasionally attain a length greater than the observed maximum immature size of 40 inches before spawning for the first time. Having regard, however, to the uncertainty in assessing the maturity stage of some of these fish it is possible that the larger maturing males may have spawned previously. The minimum size of maturing males (28 inches) on the other hand, is the same as for spent males. Similarly, the maximum size of maturing females (54 inches) is identical with that for immature females and the minimum size of maturing females (38 inches) is close to the corresponding size of spent females. The measurements of the maturing halibut in most cases therefore appear to confirm the observations on the sizes of the immature and spent fish.

Although these investigations indicate the normal minimum sizes for spawning halibut the possibility of a few fish reaching maturity at still smaller sizes cannot be entirely disregarded. Indeed, despite the rarity of ripe and running fish in commercial catches of halibut, Mr. A. Morrice, an Aberdeen great-line skipper, has reported the capture of a female halibut in this condition measuring only 75 cm (c. 29·5 inches) off the west coast of Iceland in about 250 fathoms in the latter half of May 1958. The quantity of ova extruded from this fish on being brought on board was, however, insignificant in comparison with that discharged by a larger fish on another occasion. This experience has naturally posed the question whether the first spawning of some halibut has so little visible effect on the fish that a macroscopic examination of the gonads may give no indication that the fish have spawned.

TABLE II

Maximum and Minimum Lengths of Immature and Spent Halibut respectively in Main Fishing Regions

	MALE		FEMALE	
	Maximum Immature inches (cm)	Minimum Spent inches (cm)	Maximum Immature inches (cm)	Minimum Spent inches (cm)
North Sea	37 (94)	30 (76)	54 (137)	39 (99)
N. and W. Scotland	36 (91)	35 (89)	48 (122)	39 (99)
Faroe	39 (99)	30 (76)	52 (132)	42 (107)
Oceanic Banks	35 (89)	28 (71)	48 (122)	44 (112)
Iceland	40 (102)	30 (76)	46 (117)	45 (114)

The maximum sizes of immature and the minimum sizes of spent fish in the five main regions of the N.E. Atlantic fished by Aberdeen vessels are given in Table II. These show some differences in the observed sizes from one region to another but neither they nor the measurements as a whole show any consistent trend which could be regarded as indicating any significant regional differences in the sizes at which halibut spawn for the first time.

TABLE III

Percentages of Immature and Spent Halibut in Three Inch Length Groups

MALE				FEMALE		
No. of Fish	% Immature	% Spent	Length Group inches	No. of Fish	% Immature	% Spent
30	100	—	25 - 27	32	100	—
61	70	9	28 - 30	52	100	—
79	66	11	31 - 33	89	100	—
83	29	45	34 - 36	100	100	—
53	9	55	37 - 39	72	93	4
50	2	80	40 - 42	85	73	12
21	—	90	43 - 45	46	50	30
26	—	96	46 - 48	56	32	54
22	—	91	49 - 51	30	3	80
18	—	94	52 - 54	58	5	83
3	—	100	55 - 57	29	—	100
1	—	100	58 - 60	42	—	100
—	—	—	61 - 85	95	—	100

TABLE IV

Length and Age of Spent Halibut from Oceanic Banks 1953

Length		Age—Years					
inches	cm	8+	9+	10+	11+	12+	13+
40	102	—	—	1	—	—	—
41	104	1	2	—	—	—	—
42	107	1	1	1	—	—	—
43	109	—	1	—	—	—	—
44	112	—	1	—	—	—	—
45	114	—	1	1	1	—	—
46	117	—	3	1	—	—	—
47	119	1	—	1	—	—	—
48	122	—	2	1	—	—	—
49	124	—	—	1	—	—	—
50	127	—	2	3	—	—	—
51	130	—	—	—	—	—	—
52	132	—	1	1	1	1	—
53	135	—	—	1	—	—	—
54	137	—	—	2	1	—	—
55	140	—	—	—	—	1	—
56	142	—	—	—	—	3	1
57	145	—	—	—	1	1	—
58	147	—	—	—	1	1	1
59	150	—	—	—	—	1	1
60	152	—	—	—	—	—	1

Others 14+ 57 inches (145 cm) 64 inches (162 cm)
15+ 46 inches (117 cm) 69 inches (175 cm)
16+ 60 inches (152 cm) 62 inches (157 cm)
18+ 69 inches (175 cm)

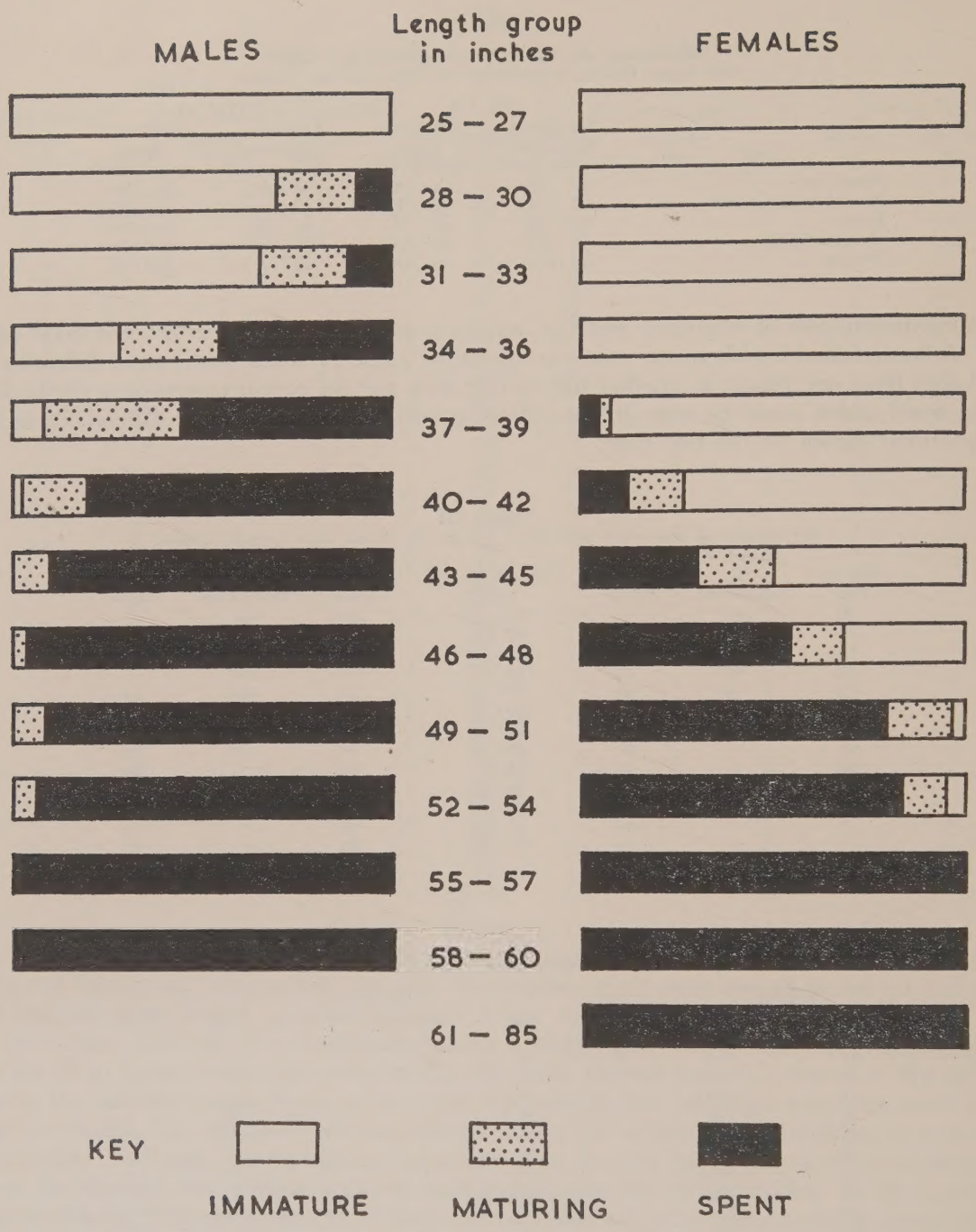

Fig. 1 Proportions of immature, maturing and spent halibut in three-inch length groups (see Table III).

Table I has been condensed in Table III (see also Figure 1) to give the percentages of immature and spent fish in 3 inch size-groups. This reveals that about 50% of male halibut spawn before they reach a length of 36 inches (91 cm) but that no female fish spawns before this size. At a length of 48 inches (122 cm) all male fish may be regarded as having spawned while only about half the females have reached maturity. All female fish above 54 inches (137 cm) in length showed evidence of having spawned at least once.

These investigations confirm that halibut spawn at a relatively large size compared with other species of demersal fish. They also confirm that male fish reach maturity at a much smaller size than the females. It is unfortunate that otoliths were not procured from any of the fish examined so that no correlation of size and age at first maturity is possible. Otoliths, however, were taken from 55 halibut, all spent fish, in the course of other studies. Although the age of these fish could not in each case be determined with absolute accuracy it is considered that the ages given in Table IV, whether true or approximate, give some indication of the age of adult halibut.

Jespersen (1917) concluded that halibut do not mature before 9 or 10 years of age at the earliest. Devold (1943) found that male fish were from 7 to 17 years old at first spawning and females from 8 to 18 years. Joensen (1954) has shown that on Faroese coastal banks the average size for five year old female halibut is 85·3 (33·5 inches) and for males 76·9 cm (30 inches). Although these sizes are higher than those obtained by Jespersen (1917 and 1936) from the same region, it seems clear that the smallest spent halibut in the present investigations, a fish of 71 cm (28 inches) caught on one of the oceanic banks, was probably not more than 6 years of age at capture. From this it may be assumed that some male halibut spawn for the first time at 6 years of age and it is possible that a few may even do so at 5 years of age. Reasoning in the same way, on the basis of the maximum size of immature male fish, it is probable that a few may delay their initial spawning until their 10th year. Similarly, the minimum size for spent females and the maximum size for immature females, when considered in relation to the age/length results of Jespersen and Joensen, indicate that some females spawn for the first time at 7 or 8 years of age and that a few may delay doing so until they are 11 or 12 years old. In this case Table IV provides some evidence in support of this view since at least one of the three eight years old fish was a spent female.

This section may, therefore, be summarised as follows; on fishing grounds extending from the North Sea to West Iceland, male halibut normally spawn for the first time at sizes ranging from 28 to 40 inches (probable age range 5 to 10 years) and females from 39 to 54 inches (probable age range 7 to 12 years). From comparison with other species there is justification for believing that most male halibut spawn before 8 years of age and most females before 10 years. This conclusion is more than borne out by the fact that all the fish recorded in Table IV were spent.

THE SPAWNING TIME OF HALIBUT

Although spent or spent and recovering fish were recorded in each month except January, when halibut landings are at their lowest, newly spawned fish were naturally more restricted in time over the year. A few individuals in this condition, both male and female, were recorded from North-west Scottish, Faroese and Icelandic grounds in March and April but recently spawned fish were not prominent in catches from any of the grounds until May and June. From the latter month their numbers declined gradually towards the end of the year. It is interesting, however, to note that spent fish appeared in quantity in May almost simultaneously on all grounds including the North Sea. It seems significant too that commercial fishing for halibut on the oceanic banks, such as Rockall and Lousy Banks, apart from an occasional exploratory trip in April, does not commence until May.

These results cannot be taken as indicating the spawning period with any precision, since spawning is known to occur in deep water (Tåning, 1936 and McIntyre, 1958) and the spent fish afterwards have to reach the comparatively shallow water of the banks before they can be caught. It is difficult, moreover, to estimate the extent of the time lag between the completion of spawning by any body of fish and their subsequent appearance on the fishing grounds but intervals of a week to three weeks do not seem unreasonable. On this basis therefore the main spawning period for halibut on the grounds investigated would appear to be within the months of April and May. Reliable evidence of spawning off Cape Dan on the coast of East Greenland in the last days of May and in the first week of June, 1953, has been given by Mr. Morrice, the Aberdeen great-line skipper already mentioned in this paper. On this occasion several male fish exuding milt and, even more interesting, a single ripe and running female were caught at a depth of 300 fathoms. In the latter half of May 1958 Skipper Morrice again caught a small number of ripe and running halibut, on west Icelandic grounds at a depth of 250 fathoms. One of these fish was

the small ripe female to which reference has been made in the last section. These records show that, at least in some localities, spawning may continue into June. They may also appear to be inconsistent with the accepted view that halibut spawn in deep water but it should be borne in mind that the sea bottom on both sides of the Denmark Strait is steep and the distance between soundings of 300 fathoms and 500 fathoms or more may be quite short.

Although the present data indicate April and May as the main spawning months in the areas under examination reference must be made to some rather contradictory evidence obtained in December 1952. On this occasion four great-line catches were landed at Aberdeen between the 15th and 30th of the month from positions ranging from 120′ NW×W to 155′ N×W of Reykjanes, Iceland (depths 200 to 250 fathoms). Halibut were well represented in each catch with large ripe females forming about 90% in the first three. In the fourth catch ripe males outnumbered the females. The most remarkable feature of these fish was the advanced condition of the reproductive organs. The roes in particular were large and fully developed with many of the ova in the glassy transparent condition. The occurrence was made memorable by the fact that eight boxes of halibut roes were offered for sale on the market. Unfortunately, the significance of this was not fully appreciated at the time and samples were not preserved. Although fishermen have visited the same grounds at the same time in subsequent years the phenomenon has not been recorded again.

The condition of the halibut on West Icelandic grounds in December 1952 suggested a spawning early in the following year. Unfortunately it was impossible to ascertain if an early spawning actually took place in 1953. It is interesting, however, to record that simultaneously with the appearance of the ripe halibut off West Iceland in December 1952 small numbers of fish were found on other grounds with exceptionally well-developed roes for the time of year. These included a few fish from Rockall, Lousy and Faroe Banks and single individuals from North-east Faroe and Whiten Head, in the North of Scotland. These latter records show that the early development of the reproductive organs in halibut was fairly general over a wide area in the second half of 1952.

An examination of the available sea temerpature records from North Atlantic fishing grounds over the period of these investigations has failed to indicate a possible explanation. Two features which suggest that the halibut on West Icelandic grounds were not actually on the point of spawning are (1) the separation of the sexes and (2) the capture of the fish at depths between 200 and 250 fathoms, although it should be noted that deeper water lay close at hand. Moreover, having regard to the glassy eggs in the West Icelandic roes it is difficult to believe that the halibut in that region did not spawn before the end of January 1953, which is much in advance of the period April to May deduced from the present examination of the maturities. Tåning (1936), from the occurrence of post-larvae and ripe fish, has already concluded that halibut in the north-eastern Atlantic spawn from March to May but mainly in April. Devold (1943), however, has pointed out that in Norwegian waters spawning takes place from late December to April. The West Icelandic records obtained in December 1952 seem, therefore, to form a link between the Norwegian and Danish results.

The possibility of the West Icelandic roes having ripened long before conditions were suitable for the actual spawning must also be considered. An early ripening of cod roes has been described by the author (1957) but in this case no glassy eggs were observed until the normal spawning period.

SEX RATIO IN HALIBUT

It has long been recognised that in individual catches by commercial vessels the sex ratio of some species of fish varies to a considerable extent. This is particularly noticeable in elasmobranchs but it is also characteristic of teleosts including flatfishes such as plaice and lemon sole. During the present investigations catches by great-line vessels exhibited some remarkable differences in the sex composition of halibut. For example, in May 1953, male halibut (73 to 87%) greatly outnumbered the females (27 to 13%) on the Viking Bank. At the same time a single landing from the northern edge of the Great Fisher Bank comprised 10% males and 90% females. Among halibut caught west of Shetland a month later males were again more numerous in the ratio of 89 to 11%. Finally with regard to West Icelandic grounds

reference has already been made to the predominance of females in catches made in December 1952 while in May 1953 females (90%) again greatly outnumbered males (10%). Although this feature occasionally seems to have some regional basis, fundamentally it would appear to be due to seasonal segregation of the sexes. In general, in the North Sea and on other grounds, where the stocks include a high proportion of immature and adolescent fish, males frequently outnumber the females in individual catches. On West Icelandic grounds, beyond the 100 fathom depth contour, and on deeper banks, such as Rockall, where stocks consist predominantly of large adult fish, females almost invariably outnumber the males.

The material in Table I may be accepted as representative and suitable for an overall assessment of the sex ratio within the various size groups. In order to cover fish of less than 24 inches all the small halibut caught by the research vessels at Faroe and at Iceland from 1955 to 1958 have been utilised together with four samples of "chicken" halibut from commercial trawlers. The results are given in Table V.

TABLE V

Sex Ratio in Halibut
North-East Atlantic 1952-57

Length Group Inches	Male		Female		Ratio M:F
	Number	%	Number	%	
8 to 24	328	49	336	51	1:1·024
25 to 36	253	48	273	52	1:1·079
37 to 48	150	37	259	63	1:1·727
49 to 60	44	22	159	78	1:3·614
61 to 85	—	—	95	100	

This shows that up to a length of 36 inches (91 cm) the numbers of each sex are about equal. From 37 inches upwards the sex ratio changes appreciably. Up to a length of 48 inches the number of males falls to a little more than a third of the total and from 49 to 60 inches to less than a quarter. As Table I shows, no male fish was examined greater than 60 inches in length but many females were measured from this size to a maximum of 85 inches.

Such changes in the sex ratio of fish with advancing size and age have already been noted in other species. The explanation is clearly due, to some extent, to the faster growth and greater maximum size of female fish compared with the males (Jespersen, 1917), but the possibility of greater natural mortality amongst male halibut, similar to that found amongst salmon, cannot be disregarded.

LENGTH/GUTTED WEIGHT RELATIONSHIP

As stated in the introduction, length and gutted weight data were collected over the period 1952-1956. As the number of fish examined at most sizes were considered inadequate, a special effort was made throughout 1957 to obtain more representative records. The results covering fish from 20 to 87 inches in length are given in Table VI.

Fish above 72 inches in length were naturally rather scarce so that the numbers measured were small. Records of fish of less than 40 inches were also less numerous than those above 40 inches but this is due to the practice on the market of displaying halibut of up to 3 feet in boxes so that fewer opportunities occurred for collecting length and weight data from individual fish in this size category. In order to obtain confirmatory records relating to fish of less than 24 inches and to include "chicken" halibut of 12 inches or less, several samples were procured from trawlers. These fish were measured and weighed (gutted) in the laboratory and the results together with some records from research vessels are set out in Table VII, in which the initial measurements in the metric system have also been converted to inches and pounds for comparison with Table VI. The mean weights for each inch length group from both tables are illustrated in Figure 2.

TABLE VI

Length/Gutted Weight Measurements of Halibut on Aberdeen Fish Market 1952-1957—All Regions

Length inches	No. of Fish	Weight Range pounds	Mean weight pounds	Length inches	No. of Fish	Weight Range pounds	Mean weight pounds
20	6	1·5- 2·0	1·9	54	93	45·5- 87·5	68·9
21	1	3·0	3·0	55	75	59·5- 98·0	73·2
22	5	2·0- 3·0	2·7	56	77	59·5-112·0	74·6
23	16	3·0- 4·0	3·5	57	105	59·5-112·0	78·8
24	22	3·5- 5·0	4·0	58	98	63·0-101·5	82·3
25	26	3·5- 6·0	4·5	59	84	63·0-108·5	87·5
26	26	4·0- 6·0	5·5	60	91	66·5-150·5	91·3
27	20	5·0- 8·0	6·5	61	74	66·5-136·5	98·1
28	18	7·0- 9·5	7·4	62	76	77·0-126·0	102·2
29	21	7·0-10·0	7·7	63	47	91·0-150·5	113·8
30	14	7·0-12·0	9·4	64	52	77·0-143·5	114·8
31	25	8·0-14·0	10·6	65	49	91·0-147·0	121·2
32	13	9·0-14·0	11·1	66	52	98·0-168·0	127·0
33	16	10·0-17·5	13·0	67	41	101·5-175·0	134·1
34	18	10·5-24·5	14·3	68	39	98·0-182·0	137·3
35	24	10·0-17·5	14·6	69	37	98·0-192·5	141·5
36	20	10·5-24·5	16·9	70	22	126·0-175·0	149·7
37	32	14·0-24·5	18·5	71	23	133·0-185·5	159·9
38	27	14·0-28·0	20·6	72	34	129·5-238·0	173·3
39	37	17·5-38·5	23·0	73	8	143·5-217·0	184·1
40	53	17·5-31·5	24·5	74	9	140·0-231·0	180·0
41	64	21·0-35·0	26·8	75	7	161·0-231·0	196·6
42	91	24·5-38·5	29·1	76	6	147·0-203·0	174·4
43	100	24·5-42·0	31·8	77	8	140·0-206·5	178·5
44	96	24·5-42·0	32·9	78	5	196·0-245·0	219·1
45	99	28·0-45·5	35·8	79	1	168·0	168·0
46	92	28·0-45·5	38·4	80	1	217·0	217·0
47	82	31·5-52·5	41·7	81	2	164·5-241·5	203·0
48	81	31·5-56·0	44·4	82	1	203·0	203·0
49	65	38·5-63·0	47·9	83	1	276·5	276·5
50	82	42·0-70·0	51·8	84	1	178·5	178·5
51	65	42·0-80·5	54·7	85	2	234·5-245·0	239·8
52	76	49·0-87·5	60·3	86	—	—	—
53	76	49·0-91·0	63·3	87	1	276·5	276·5

TABLE VII

Length/Gutted Weight Measurements of "Chicken" Halibut from Faroe and Iceland

Length cm	Weight Range gm	No. of Fish	Mean Weight gm	Length to nearest inch	No. of Fish	Mean weight gm	Equivalent weight ounces
19	90	2	90·0				
20	100	1	100·0	8	5	103	3·6
21	115-120	2	117·5				
23	140	2	140·0	9	2	140	4·9
36	450-480	4	468·0	14	4	468	16·4
38	497-582	2	539·5				
39	601-664	4	622·3	15	6	595	20·9
40	595-684	9	644·4				
41	650-758	10	695·1	16	19	671	23·7
42	670-822	21	747·5				
43	751-888	10	820·1	17	40	794	28·0
44	800-964	9	872·8				
45	845-974	5	912·4				
46	950-1070	3	1018·0	18	8	952	33·4
47	1067-1135	3	1093·7				
48	1119-1174	2	1146·5	19	5	1115	39·2
51	1370-1385	2	1377·5	20	2	1378	48·6
52	1330-1440	2	1385·0				
53	1370-1440	2	1405·0	21	4	1395	49·1
56	1683-1771	2	1727·0	22	2	1727	60·8
59	2092	1	2092·0	23	1	2092	73·6
60	2176-2346	5	2266·6				
62	2400-2623	2	2511·5	24	7	2337	82·3
63	2575	1	2575·0				
64	2632-3171	2	2901·5	25	3	2793	98·3
65	2897-2992	2	2909·5				
66	3067-3158	2	3112·5	26	8	3086	108·6
67	2988-3557	4	3160·3				
68	3588	1	3588·0				
69	3401-3462	2	3431·5	27	3	3484	122·6

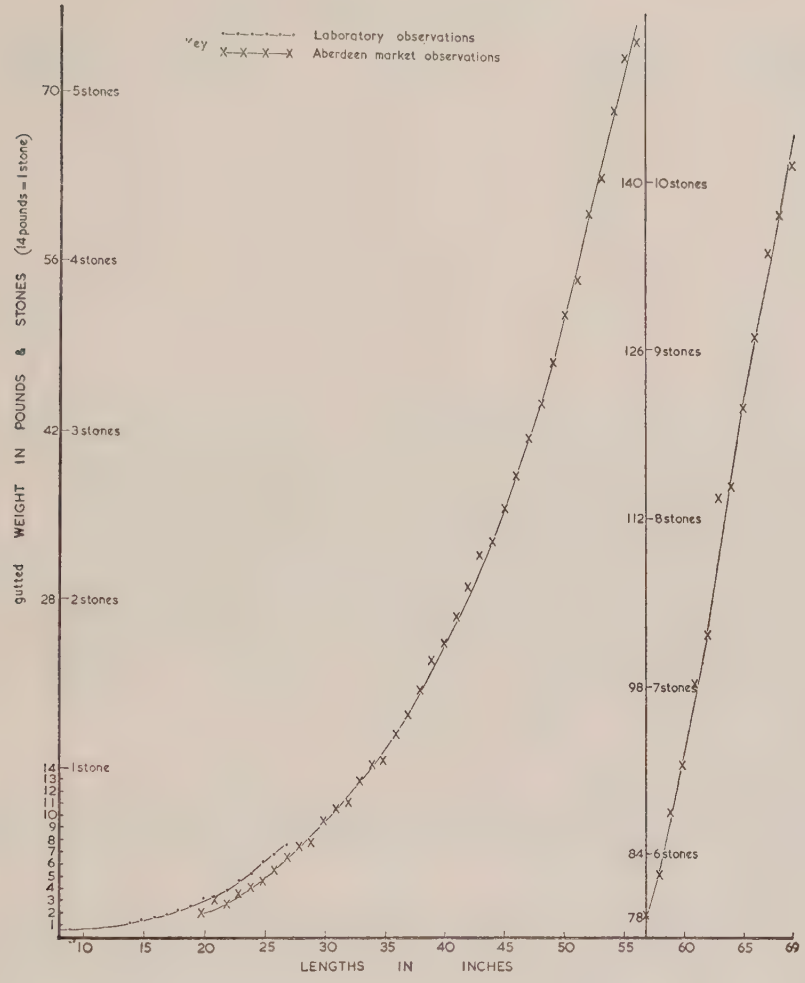

Fig. 2 Length/gutted weight relationship in halibut; average weights—all regions—January to December.

A discrepancy in each size group of from one to one and a half pounds in the weights of fish of 20 to 27 inches in length, where the two curves overlap, is at once noticeable. The lower values representing the market observations are clearly due to the practice of recording weights to the nearest quarter of a stone ($3\frac{1}{2}$ pounds) below the actual weight observed. Accordingly all market weights may be anything from 0 to 3 pounds lighter than their true weight and the differences in the averages for each length group compared with the accurate laboratory observations are thus understandable. If corrections were applied to the market records the two curves in Figure 2 would practically coincide.

These investigations with emphasis on large halibut may be regarded as complementary to similar work by Jespersen (1917) on "chicken" halibut. If allowance is made for Jespersen having dealt with whole fish instead of gutted the two sets of results are in fairly close agreement.

Tables VI and VII, and Figure 2 reveal some interesting features of the halibut's growth. Jespersen has referred to the increasing weight increment per centimetre's growth among the small fish. Table VI shows that the weight increment continues to increase steadily per inch of growth (see Figure 2) up to a length of 72 inches, after which scarcity of records render the averages rather less reliable.

TABLE VIII

Length and Weight Increments in Halibut and Rates of Increase

Length inches	Weight pounds	Increment pounds	Length Increase	Weight Increase
12	0·67	—	—	—
24	5·14	4·47	× 2	× 7·67
36	16·94	11·80	× 3	× 25·28
48	44·38	27·44	× 4	× 66·24
60	91·28	46·90	× 5	× 136·24
72	161·28	70·00	× 6	× 240·72
84	227·50	66·22	× 7	× 339·55

Table VIII gives the average weights of halibut at 12 inches and at intervals of 12 inches up to a maximum of 84 inches. (The weight for fish of 84 inches was obtained by averaging all halibut of 81 to 87 inches). The third column in this table shows the weight increment for each 12 inches of growth. In the fourth and fifth columns the increases in length and in weight are indicated in terms of multiples of the length and weight of a 12 inch fish. This shows that a fish of this length in doubling its length increases its weight by seven or eight times; in trebling its length it increases in weight by twenty-five times and so on up to a sevenfold increase in length, which results in the halibut increasing its weight by about three hundred and forty times. These results have been examined by members of the statistical section who found that the weight/length relationship estimated by the method of least squares from average weights at each inch is

$$W = 0{\cdot}0001123L^{3{\cdot}3294}$$

where W is in pounds and L in inches.

Another remarkable feature of Table VI is the wide range in the weights of halibut of the same length. Table IX has been prepared to emphasise this point and also to demonstrate the scatter of the fish at the different weights.

Even "chicken" halibut (Table VII) shows differences in weight but this feature becomes accentuated in the larger fish. At lengths of 34 or 36 inches the maximum weight of 24·5 pounds is 2·3 times the minimum weight of 10·5 pounds. At this size it is probable that the weighing of fish to the nearest $3\frac{1}{2}$ pounds may result in some error which exaggerates the weight range but this explanation cannot account for the marked differences in large fish, of 60 inches for example, where the ratio of minimum to maximum weight is again 1 to 2·3. In general, however, the maximum weight is from 1·5 to 2·0 times greater than the minimum.

While the wide weight range in fish of the same length may appear surprising, it is perhaps not so remarkable to fishermen and merchants who handle halibut daily. Even a superficial knowledge of the halibut market will soon reveal the great variety in the shape, girth and condition of this species. In shape, for example, halibut vary considerably in the depth of the body between the dorsal and the anal fins. Furthermore, some fish taper quickly towards the tail while others continue relatively deep in the body posteriorly. In some fish too, the caudal peduncle appears comparatively thicker than in others. These variations together with marked differences in thickness are reflected in the variable girths of the fish at comparable points along their entire body length.

These anatomical differences in halibut would appear to be one reason for the pronounced weight differences at each individual length. As they occur in catches from all fishing grounds there is no evidence from the present studies that the deeper-bodied or thicker fish are characteristic of any particular region.

Changes in the condition of halibut throughout the year must also be considered as a cause of variable weights. In order to examine this possibility, average weights have been calculated for each size group from 40 to 65 inches (the lengths for which records are most numerous) on a seasonal basis—(1) April to June, (2) July to September and (3) October to March (Table X).

TABLE IX

Weight Range in Halibut
(all Gutted Weights)
Weight in pounds

Length Inches	3·5	4	4·5	5	5·5	6	6·5	7	7·5	8	8·5	9	9·5	10	10·5	11	11·5	12	12·5	13	13·5	14	14·5	15	15·5	16	16·5	17	17·5	18
24	8	9	1	4																										
25	4	8	2	10	—	2																								
26	—	1	—	12	—	13																								
27	—	—	—	2	—	8	—	9	—	1																				
28	—	—	—	—	—	—	—	13	1	1	—	2	1																	
29	—	—	—	—	—	—	—	13	—	3	—	4	—	1																
30	—	—	—	—	—	—	—	1	—	2	—	5	—	3	1	1	—	1												
31	—	—	—	—	—	—	—	—	—	1	—	1	—	6	14	—	—	1	—	—	—	2								
32	—	—	—	—	—	—	—	—	—	—	—	1	—	1	4	3	—	3	—	—	—	1								
33	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	—	—	2	—	—	—	9	—	—	—	—	—	—	1	—(24·5)
34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	1	—	—	—	12	—	—	—	2	—	—	—	1
35	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	15	—	—	—	1	—	1	5	

Weight in Stones (1 Stone=14 pounds)

	·75	1	·25	·50	·75	2	·25	·50	·75	3	·25	·50	·75	4	·25	·50	·75	5	·25	·50	·75	6	·25	·50	·75	7	·25	·50	·75	8
36	1	6	9	3	1																									
37		1	22	8	1																									
38		2	4	17	3	1																								
39			4	18	11	2	—	1	1																					
40			1	11	30	9	2																							
41				4	24	29	6	1																						
42					12	46	25	7	1																					
43					1	35	30	25	8	1																				
44					4	15	34	26	14	3																				
45						4	18	37	31	7	2																			
46						3	8	22	26	22	11																			
47							4	11	16	23	15	10	3																	
48							1	5	11	20	17	22	3	2																
49									6	7	16	19	10	6	—	1														
50										9	15	14	14	15	10	3	1	1												
51										3	6	10	13	15	5	9	2	1	—	—	1									
52												5	6	17	19	14	5	7	1	—	1	—	1							
53												1	6	11	17	11	12	9	5	2	1	—	—	1						
54											1	—	—	5	8	13	18	21	8	9	3	5	2							
55															2	8	9	15	13	12	8	6	—	—	1	1				
56															2	8	8	16	8	12	9	8	2	3	—	—	—	—	—	1
57															3	5	5	11	19	20	5	12	6	11	3	2	1	—	1	1
58																1	3	6	13	13	11	22	8	7	7	4	3			
59																1	—	4	3	5	13	11	8	15	10	5	6	2	1	

	·75	5	·25	·50	·75	6	·25	·50	·75	7	·25	·50	·75	8	·25	·50	·75	9	·25	·50	·75	10	·25	·50	·75	11	·25	·50	·75	12	·25	·50	·75	13
60	2	—	—	8	11	13	7	16	8	7	5	5	5	1	1	—	1	—	—	—	—	—	—	—	1									
61	1	2	—	—	1	3	7	16	4	10	6	7	7	4	1	2	—	1	1	—	1													
62				2	2	2	6	7	5	9	8	9	6	5	3	8	1	3																
63								1	2	3	3	4	6	9	4	3	3	2	1	3	2	—	—	—	1									
64				1	—	—	—	1	2	1	6	4	6	6	6	1	5	3	2	3	1	3	1											
65								3	2	2	2	1	—	5	6	6	1	2	3	5	1	2	3	5										
66										2	1	1	3	4	4	5	4	4	5	7	1	1	2	2	1	2	2	—	—	1				
67											2	—	2	2	1	5	2	5	3	2	—	2	3	2	2	1	2	1	1	1	1	1		
68										1	—	2	1	1	—	1	3	3	2	4	3	3	—	5	2	1	3	—	2	1	—	—	—	1

TABLE X

Average gutted weights of Halibut According to Season in Stones (1 stone=14 pounds=6·35 Kg.)

Length in inches	April to June No. of Fish	April to June Average Weight	July to September No. of Fish	July to September Average Weight	October to March No. of Fish	October to March Average Weight
40	11	1·66	29	1·73	13	1·87
41	17	1·88	25	1·85	22	1·99
42	25	2·10	39	2·05	27	2·11
43	31	2·27	38	2·20	31	2·34
44	38	2·32	32	2·33	26	2·43
45	40	2·53	28	2·53	31	2·65
46	37	2·67	38	2·80	17	2·78
47	34	2·89	32	2·99	16	3·16
48	33	3·06	25	3·21	23	3·27
49	23	3·26	27	3·46	15	3·57
50	31	3·52	27	3·83	24	3·77
51	28	3·96	21	3·89	16	3·84
52	28	4·33	25	4·30	23	4·30
53	31	4·36	22	4·42	23	4·82
54	32	4·70	35	4·90	26	5·21
55	28	5·13	32	5·29	15	5·30
56	35	5·14	24	5·59	18	5·33
57	36	5·49	34	5·84	35	5·56
58	48	5·74	35	6·09	15	5·83
59	31	6·06	34	6·38	19	6·30
60	38	6·13	30	6·86	23	6·74
61	27	6·74	37	7·16	10	7·20
62	32	7·00	29	7·73	15	7·10
63	18	8·01	19	8·29	10	8·03
64	21	7·92	25	8·52	6	7·83
65	23	8·30	20	9·14	6	8·46

Table X shows that fish caught from April to June on an average weigh less than those taken in the other periods. In fish of 40 to 52 inches this difference varies from 1 to 4·3 pounds while in larger fish it ranges upwards to a maximum of 11·75 pounds at 65 inches. The greater loss of weight in the bigger fish is to be expected in view of their greater spawning potential, while the 40 to 52 inch size group includes some fish which have not matured and are therefore not subject to loss of weight from spawning. The loss in weight of halibut from April to June would therefore appear to be due mainly to the effects of spawning on the fish.

TABLE XI

Average gutted Weights of Halibut by Regions—April, May, June in Stones (1 Stone=14 pounds=6·35 kg.)

Length in inches	Scottish Waters No. of Fish	Scottish Waters Average Weight	Faroe No. of Fish	Faroe Average Weight	Oceanic Banks No. of Fish	Oceanic Banks Average Weight	Iceland No. of Fish	Iceland Average Weight
40	7	1·75	3	1·42	1	1·75	—	—
41	4	2·00	9	1·89	3	1·75	1	1·75
42	7	2·25	7	2·04	10	2·08	1	1·75
43	10	2·33	8	2·09	12	2·31	1	2·75
44	6	2·46	17	2·28	15	2·32	—	—
45	3	2·42	21	2·51	15	2·58	1	2·25
46	11	2·68	8	3·00	17	2·52	1	2·50
47	7	3·14	8	2·91	18	2·75	1	3·50
48	7	3·29	7	3·32	17	2·85	2	3·13
49	5	3·45	6	3·25	11	3·23	1	2·75
50	6	3·71	8	3·63	15	3·42	2	3·25
51	4	4·25	9	3·97	15	3·88	—	—
52	9	4·36	8	4·50	8	4·28	3	3·92
53	6	4·38	6	4·50	18	4·29	1	4·75
54	9	4·97	8	4·78	9	4·64	6	4·29
55	5	5·30	8	5·25	13	4·98	2	5·13
56	6	5·38	8	5·44	11	5·11	10	4·80
57	3	5·67	8	5·47	12	5·42	13	5·54
58	7	6·04	8	5·69	14	5·69	19	5·68
59	3	6·33	7	6·18	8	6·25	13	5·83
60	4	7·56	2	6·25	15	5·93	17	5·96
61	5	7·20	5	6·60	9	6·83	8	6·44
62	6	7·46	7	7·46	11	6·57	8	6·84
63	7	8·32	4	8·06	3	7·67	4	7·69

Table X also shows that the average weights of halibut of 40 to 55 inches in length are greatest during winter, whereas fish of 56 inches and over are heaviest from July to September, i.e. after feeding and recovery from spawning has been in progress for some time.

The possibility of a difference in the weights of male and female fish of the same length must also be considered. Unfortunately, no sex distinction was made during the length weight investigations. However, on the basis of the very wide range in weight of fish at each length from 60 inches upwards, all of which are females, it would appear that any difference due to sex is insufficient to mask the effects of differences due to other causes.

TABLE XII

Average gutted Weights of Halibut by Regions—July, August, September in Stones (1 Stone = 14 pounds = 6·35 kg.)

Length in inches	Scottish Waters		Faroe		Oceanic Banks		Iceland	
	No. of Fish	Average Weight	No. of Fish	Average Weight	No. of Fish	Average Weight	No. of Fish	Average Weight
40	5	1·75	6	1·71	18	1·74	—	—
41	4	1·81	4	1·88	17	1·85	—	—
42	6	2·17	6	1·92	25	2·04	2	2·25
43	2	2·25	18	2·21	17	2·21	1	2·00
44	2	2·75	10	2·30	19	2·33	1	1·75
45	2	2·63	13	2·56	12	2·48	1	2·50
46	6	3·04	13	2·88	19	2·66	—	—
47	6	3·13	9	3·03	15	2·93	2	2·88
48	7	3·46	8	3·16	9	3·06	1	3·25
49	2	3·63	11	3·45	14	3·45	—	—
50	13	3·96	5	4·00	6	3·50	3	3·67
51	4	4·44	5	4·10	12	3·63	—	—
52	8	4·50	6	4·29	7	4·14	4	4·19
53	4	4·75	2	4·38	10	4·45	6	4·17
54	11	5·18	5	5·05	12	4·71	7	4·68
55	13	5·50	7	5·07	8	5·22	4	5·13
56	12	5·96	4	5·63	3	5·00	5	5·05
57	10	6·20	5	5·90	12	5·63	7	5·64
58	8	6·59	5	6·35	8	5·94	14	5·80
59	7	6·93	5	6·35	10	6·23	12	6·21
60	6	7·21	3	7·00	9	6·83	12	6·67
61	8	8·09	7	7·32	10	6·40	12	7·06
62	13	8·35	3	7·50	6	7·04	7	7·29
63	8	9·44	2	7·38	4	7·38	5	7·55

The data have also been examined on a regional basis, while retaining the main spawning and feeding, seasonal distinctions (see Tables XI and XII). These show that in each season the North Sea averages are higher than those for Faroe and that the latter are in turn higher than the equivalent values for the oceanic banks and Iceland. During the feeding season (Table XII), the North Sea averages stand out clearly from the others, indicating heavier fish at nearly every length. (See Figure 3).

These regional differences vary up to 7 pounds during the spawning season and to as much as 10·5 pounds (exceptionally 14 pounds) from July to September. In the absence of any obvious anatomical difference in the fish these regional variations must be regarded as being due to the condition of the fish.

In this connection, reference should be made to Cutting's (1951) demonstration of the loss in weight of fish during transit from the fishing grounds to the market. Cod and haddock lose a variable percentage according to their location in the fish hold and to the length of the voyage. This loss is greatest where pressure of overlying fish and ice is heaviest and may be as high as 18% in individual fish. However, where fish are subjected to a minimum of pressure, as at the top of the hold or in shelved cod, the average loss may be as low as $2\frac{1}{2}$%. A similar loss may therefore be expected in halibut but in view of its firmer flesh and of the preferential treatment given to it by fishermen, the loss is unlikely to exceed $2\frac{1}{2}$% and is probably less. At the same time it is obvious that if a minor loss in weight does occur from this cause the loss will undoubtedly be greatest in catches from distant grounds such as west Iceland and least in those from the North Sea. Assuming a loss of $2\frac{1}{2}$% in the weight of halibut from the more distant grounds, this would account for only a proportion of the difference in the regional averages, amounting to rather more than 25% of the difference from April to June and to rather less than 25% from July to September.

The halibut stocks in the North Sea and at Faroe are predominantly composed of immature and adolescent fish. Adult fish taken during feeding incursions on these grounds are seldom present in great

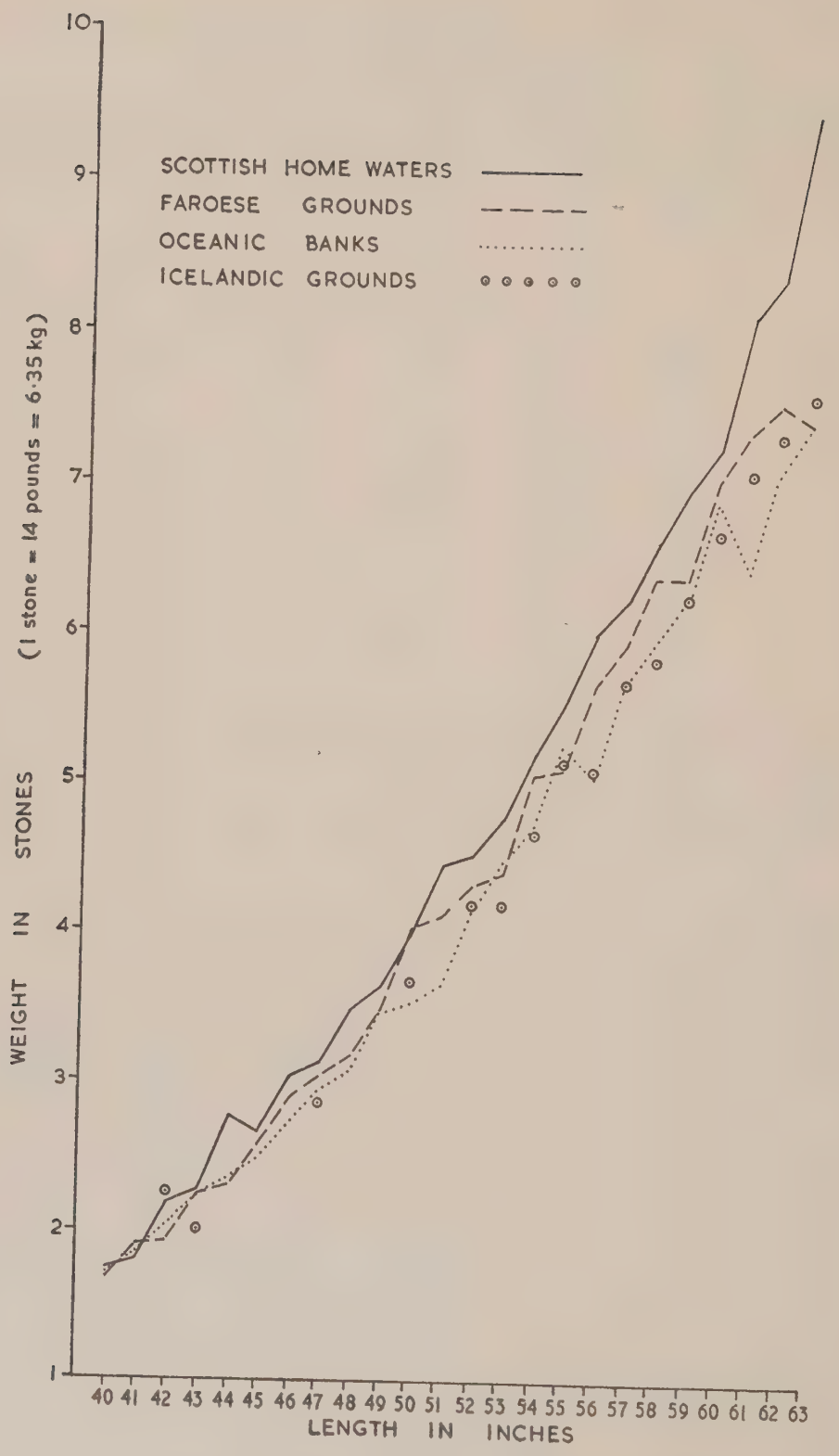

Fig. 3 Length/gutted weight relationship in halibut; average weights—July, August, September (see Table XII).

quantity. In this respect these grounds differ from the deep oceanic banks, such as Rockall and Lousy, and West Icelandic grounds beyond the 100 fathom line where the stocks consist almost exclusively of adult fish. Adult fish, with which the present problem is mainly concerned, are therefore less numerous in the North Sea and at Faroe than in the deep water regions. Competition for the available food among adult or large fish should therefore be less severe in the North Sea and at Faroe. Since competition for food is mainly confined to fish of the same size (McIntyre 1953) and since large fish of other species are also relatively fewer in the North Sea and at Faroe than on the Oceanic banks and on West Icelandic grounds this should result in better feeding and in a general improvement in the condition of all large fish compared with those on the more densely populated grounds.

The differences in the weights of halibut of the same length are therefore due to a combination of factors including anatomical variations in individual fish, the effects of spawning, differences in regional feeding and, in some limited degree, differences in the weights of the sexes and loss of weight during transit from distant fishing grounds to the market.

SIGNIFICANCE OF RESULTS IN RELATION TO CONSERVATION OF STOCKS

Although adult halibut, on the whole, frequent grounds on which the only possible method of fishing is by great-line and are thus subjected to a selective method with relatively little consequent danger of overfishing, the young immature and earlier adolescent stages are found only at trawlable depths. It is also recognised that the nursery grounds inhabited by halibut during the first three or four years of life are comparatively restricted in extent. In the north-east Atlantic, for example, young halibut are found in large numbers close to the Faroe Islands and on certain parts of the west coast of Iceland. The species is thus particularly vulnerable to trawlers in its early years and for this reason requires consideration in regard to conservation.

So far the halibut has not been included in any list of fishes specifying minimum marketable sizes. It is obvious from the section on the length at first maturity that any minimum size, comparable with the sizes at present in force for other species, would be quite inadequate to ensure the survival of any halibut until it spawns, still less to ensure rational fishing. Furthermore, decisions as to minimum marketable sizes must be taken in relation to other species caught on the grounds and to their ability to penetrate cod-end meshes of different dimensions. Little attention appears to have been given to the escape of small halibut from the cod-end of trawls and unfortunately Scottish research records provide meagre data on the subject. The available records from Faroese and Icelandic grounds are nevertheless worthy of examination.

TABLE XIII

Numbers of Halibut Retained by (R) and Escaping from (E)
Cod-ends of Different Mesh Size
Scottish Research Vessels 1950-1958

Mesh Size in mm		Length of Fish in cm																	
		<15	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Totals
70-75	R	—	—	4	8	6	5	8	6	2	6	4	9	11	7	11	15	11	113
	E	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
80	R	—	—	—	—	—	—	—	—	3	4	12	12	11	8	2	—	—	52
	E	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
90	R	—	—	—	—	—	—	—	—	1	5	6	8	10	15	9	5	1	60
	E	—	—	—	—	—	—	—	—	1	—	—	1	1	—	—	—	—	3
100-110	R	—	—	—	—	—	—	—	—	6	5	24	36	44	43	48	53	36	295
	E	3	—	—	—	—	—	1	1	3	9	14	8	13	8	2	—	1	63

Table XIII summarises the numbers of small halibut caught at each centimetre size group from 15 to 30 cm since 1950. Distinction is made between fish retained by and those escaping from cod-ends of various mesh sizes (escaping fish being retained in a small-meshed cover fitted over the cod-end for this purpose). The table reveals two remarkable features:—

1. The scarcity of halibut of less than 25 cm.
2. The small numbers of halibut escaping from the cod-end.

The scarcity of the smallest bottom sizes of halibut is a problem which others have encountered (Jespersen 1917, Joensen 1954). It is doubtful if any satisfactory explanation has yet been advanced as to why this should be, but the most probable explanation is that they are mainly located within territorial waters. The results are inadequate for a study of the various release points for the different mesh sizes but they do suggest certain trends. In the first place only two small fish, each less than 16 cm, escaped through meshes of 70 to 75 mm; all halibut of 16 cm and upwards were retained. A single fish of 22 cm penetrated an 80 mm cod-end while the remaining fish of this size and above were retained. With a mesh of 90 mm escapes included fish of up to 26 cm and retensions from 22 cm upwards. With mesh sizes ranging from 100 to 110 mm escapes included halibut up to a length of 30 cm while fish as low as 22 cm were retained. The indications are, therefore, that the 50% release point for halibut from cod-ends of 100 to 110 mm mesh is somewhere between 22 and 24 cm and may even be lower than for plaice (plaice 50% retention length for 100 mm mesh=22·0 cm—Report of Ad Hoc Committee, 1957).

Although the small halibut is a narrower fish than the plaice or lemon sole of the same length, it is at the same time thicker and more rigid morphologically than either of these two species. These factors might well account for its relative inability to escape from cod-ends.

If it is assumed that halibut of less than 25 cm (9·8 inches) are mainly resident within territorial waters, it is clear that as they grow and gradually move seawards they will ultimately run the risk of capture by trawlers. Earlier in this paper it has been shown that a halibut of 12 inches (30·5 cm) weighs on an average 0·67 pounds (304 gm); allowing for the weight of head, skin, bones and tail it is unlikely that half of this weight would consist of edible flesh. One has merely to consider the length and weight increments in Table VIII to appreciate the advantage to be gained by allowing small fish to live and grow. A fish of 12 inches would double its length and increase its weight by seven or eight times in about two years. In a further three years the same fish would treble its length and increase in weight by twenty-five times. In order to attain a length of 48 inches and an average weight of 44 pounds a 12 inch halibut would have to survive for eight to ten years.

In order to avoid destruction of potential weight of fish it is essential to conserve stocks and this is as necessary for halibut as for any other species. So far, at international level, only two methods of conservation have been attempted—firstly by fixing standard sizes for the mesh in cod-ends and secondly by laying down minimum marketable sizes. As regards mesh size the standard agreed upon must be a compromise, which takes into account the species on which the fishery is based. Accordingly no special size of mesh can be laid down for halibut alone. As already stated, no minimum landing size has yet been determined for halibut. In view of the capture of small immature halibut by trawlers, and with particular regard to the sizes retained in a cod-end of 100 to 110 mm mesh, the desirability of a minimum size for this species is obvious. Measurements of young halibut landed at Aberdeen during 1947 and 1948 show that fish as small as 26 cm were included in the catches. In recent years McIntyre's investigations (as yet unpublished) of the stocks of young halibut at Faroe have confirmed this and have shown that samples occasionally contain even smaller fish. At the same time there is evidence that small fish of less than 30 cm are discarded by some fishermen.

Tagging experiments and minor investigations carried out some years ago on the viability of small trawl-caught halibut show that fish of this size can survive capture, particularly if liberated immediately. It may be concluded therefore that the return to the sea as quickly as possible of all halibut below a certain minimum landing size would ensure the survival of a fair proportion of these fish. This action would no doubt result in an immediate reduction in the landings of small halibut, but the loss would be transient and the subsequent growth of the discarded fish would not only be to the advantage of the trawlers but would also help to ensure that larger numbers reach the size at which halibut move to deeper water. In this way the great-line fishery for halibut would benefit as would also, in course of time, the stocks of adult fish bearing the spawning potential for the future.

SUMMARY

Investigations on commercial and research vessel catches from the North Atlantic have shown that male halibut normally spawn for the first time at sizes ranging from 28 to 40 inches and females from 39 to 54 inches.

Spawning takes place mainly in April and May but evidence of an earlier spawning, based on the occurrence of well developed roes in fish caught in December 1952, is discussed.

In the early years of the halibut's life male and female fish are present in equal numbers but with increasing age and size the females outnumber the males and all the large fish of 60 inches and over were found to be females. The length/weight relationship is studied. Halibut of the same length vary greatly in weight. This is due to various factors including anatomical, seasonal and regional differences.

The significance of these results is considered in relation to the halibut fisheries and the need for conservation of such a valuable species is noted.

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